Fresnel lens Gamma Ray Telescope

ACS

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ACS

- ACS Overview
- Requirements
- Assumptions
- Control Modes
- Disturbances/Sizing
- Sensors and Actuators
- Future Technology
- Comments/Concerns

ACS Overview

- **Purpose of Study**
  - Possible solution direction
  - Provide insight into potential problem areas
- **ACS technical challenges**
  - Translation requirements
    - High precision translation sensors must be developed (*metrology*)
    - Coupled position/attitude determination and control
- **ACS requires inter-spacecraft control to meet challenges**
  - Pseudo-Rigid formation
    - Lining up the two spacecraft (*assumed in this work*)
  - Formation pointing
    - High performance ACS system

ACS - Assumptions

- Metrology → relative position determination and control in place
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- Inertial pointing
- Life/goal of system — 3/5 years
- Orbit: — Heliocentric, 1AU from sun, Drift orbit
- Mass and Inertia
  - Detector: [7504.0 3742.0 4699.0] kg-m^2;
  - Lens: [2407.0 2407.0 1801.0] kg-m^2
- Effective Area:
  - Detector: SA- 46 .3 m^2
  - Lens: - 25 m^2

ACS Driving Requirements & Assumptions

- Pointing Accuracy (3σ) 60.0 arcsec / 100.0 microarcsec*
- Attitude knowledge (3σ): 10.0 arcsec / 1.0 microarcsec*
- Position Control: 10 cm
- Position knowledge: 4.0 mm
- Attitude Slew Rates: 180 deg/week

* Accuracies with respect to coupled line of sight problem

ACS
Control Modes

- **Science Mode** **3-axis stabilized, inertial pointing;**
  - Use metrology and attitude sensor (detector s/c has fine metrology sensor)
  - Lens: Wheels to control attitude
  - Detector: Wheels and micro thrusters to control attitude/position
- **Safehold Mode** ***Sun Acquisition, array→sun pointing;***
  - Use IRU, CSS and wheels to null attitude rates and point solar array normal to the sun
  - Find inertial attitude and relative positions with ST and metrology system
  - Use accelerometer and thrusters to null translation rates and *unload wheel momentum*
- **Orbit/formation Maintenance Mode**
  - Use gyro and metrology system sensor
  - Thrusters (micro and standard) provide both Delta V and attitude control actuation.
- **Acquisition Mode**
  - Use coarse ST to point both lens and detector crafts to target
  - Lens craft remains fixed (only rotates), move detector
  - Use coarse Metrology sensor/thrusters to guide detector into FOV of fine metrology sensor
  - Use fine Metrology sensor/micro thrusters to lock in line of sight position (pseudo-rigid structure).

ACS
Disturbance Torques

- There are no significant gravity gradient or aero torques
- Solar Pressure disturbance torques are the only significant torques

Lens Craft

Solar Pressure Disturbance Torque = 2.78e-4 Nm

Detector Craft

Solar Pressure Disturbance Torque = 3.35e-6 Nm

Actuation Approach

- **Lens Craft**
  - Use 4 Ithaco A –wheels as actuator for fine control and re-pointing, considering using an isolation package to reduce noise
  - Use cold gas for momentum unloading (less than 5 Kg propellant)
  - Use cold gas as back up to null tip off rate
- **Detector Craft**
  - Use 4 Ithaco A-wheel to perform angular rotation, turn wheel off during science mode
  - Use milli/micro thruster for fine control
  - Use thruster to maneuver and unload momentum
  - Use thruster as back up to null tip off rate

Position and Attitude Sensing and Control

- **Needed:**
  - High precision metrology (position) system assumed
  - High precision ACS
- **Possible solution direction**
  - Tie Formation attitude to the stars
    - High Performance ST, High Performance Gyro
- **Supplement**
  - Tie Formation attitude to the stars
    - Super Gyro: Gravity Pro B type of Gyro
    - Super Star Tracker
    - Radio Interferometry
  - Formation ➔ pseudo rigid structure (Metrology)
    - Relative position system
      - translation in the x-y focal plane CCD based micro star tracker
      - Laser/beacon
    - Gimbaled or oversized detector

Formation Attitude

- **Fine Star Tracker, High Performance Gyro**
  - Description
    - High Performance system (ST & IRU)
  - Advantages
    - Maturity: TRL 9
  - Disadvantages
    - Small FOV
    - Require a coarse star tracker

ACS Components (Lens)

Baseline Design	Cost is SWAG				Power	Power	Power
			Cost	Mass	Orbit Avg	Peak	Safehold
Components	Model	Quantity	($K)	(Kg)	(W)	(W)	(W)
ACE	(Based on TRMM)	2		24	28	34	28
Coarse Sun Sensor	Adcole 11866	8		0.04	0	0	0
IRU	TARA II Two Axis Rate Gyro	3		5.7	20.7	22.5	20.7
Ball Aerospace Star Tracker	CT-633	2		5	30	30	0
Laser/Beacon System		2	TBD	TBD	TBD	TBD	TBD
Electronic Valve Drive (EVD)	(Based on MAP EVD)	1		10	13	17	0
Reaction Wheel	Ithaco A (USA)	4		2.55	33.6	80	33.6
		Total =		**47.3**	**125.3**	**183.5**	**82.3**

ACS Components (Detector)

Baseline Design	Cost is SWAG				Power	Power	Power
			Cost	Mass	Orbit Avg	Peak	Safeho
Components	Model	Quantity	($K)	(Kg)	(W)	(W)	(W)
ACE	(Based on TRMM)	2		24	28	34	28
Coarse Sun Sensor	Adcole 11866	8		0.04	0	0	0
IMU	LN-200S	2		1.5	24	30	24
Micro arcsec Star Tracker	TBD	2	TBD	TBD	TBD	TBD	0
Ball Aerospace Star Tracker	CT-633	2		5	20	20	0
Electronic Valve Drive (EVD)	(Based on Map EVD)	1		10	13	17	0
PPT	TBD	3		5	5	5	5
Reaction Wheel	Ithaco A (USA)	4		2.55	33.6	80	33.6
		Total =		**48.1**	**123.6**	**186**	**90.6**

ROM ACS Labor Cost

GNC / Systems Engineering	
ACS Design & Analysis Labor	
ACS Hardware Labor	
ACE Hardware Labor	
Hybrid Dynamic Simulator (HDS)	
Integration and Testing	
GRAND TOTAL	$

Note: Estimated cost derived from existing programs, such as MAP
:complexity= 2 cost in $K

ACS Requirements Imposed On Other Sub-Systems

- Lowest structural mode ➔ Mechanical
  - Effects on ACS Controller bandwidth
- Communication between spacecraft ➔ Communication
- Position information (TBD) ➔ Metrology
- Maximum cp-cg offset is 10% of height Mechanical

Future Technology

- **Technology**
  - Metrology ➔Laser/beacon/detector
    - Detector (micro arc-second star tracker) resolution (x-y detector)
  - Thermal control of sensor
  - Vibration isolation of actuators
  - Formation Flying and Acquisition Algorithms
- **Multiple lens or detector formation**

ACS Concerns and Comments

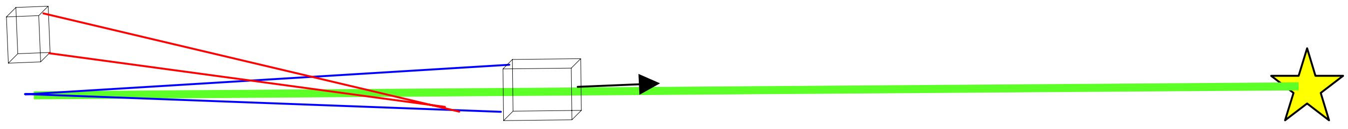
- **Concerns**
  - Attitude and Position are coupled!!!!
  - The feasibility of achieving micro arc second imaging when spacecraft is controlling only to arc minute accuracy
  - *Fine position control thrust firing effect effect on life and reliability of thrusters (start stop cycle)*
  - Contamination of thruster firing on detector wrt metrology sensor
  - Formation safehold
  - Fuel Slosh

- **Comments**
  - Expandability/modularity of formation to accommodate addition s/c or perform other missions
  - Lens spacecraft defines the desired position/attitude for the detector spacecraft?
  - Consider putting the super star tracker (metrology) in a high precision gimbal system
  - Redo disturbance analysis as s/c configurations change

Supplement

Pseudo-Formation Structure

- **Laser/beacon type relative position sensor**
  - Description: control the motion of the detector such that the laser from the beacon hits the center of the detector
    - Coarse positioning: Lower grade oversized detector
    - Laser for the fine positioning
      - mounted on piezoelectric actuators
  - Rigid (Tight): Precision track and control of position
  - Flexible (Soft): control threshold
  - Track the drift take it out in the post processing



♦ Laser/beacon type relative position sensor

- Advantages
  - Relative positions
  - Vehicle collision avoidance
  - Different levels of control
  - Can accommodate large formations
    - Individual vehicles have different wavelength/frequencies
- Disadvantages
  - (tight) ➔Control chatter in the thrusters will effect their efficiency and life
  - May need piezo-electric gimbaled actuator on fine positioning system
  - Maturity:
    - The detector (photons required for a given accuracy).
    - Need a star tracker type of detector

♦ Automated Formation Flying (AFF) system

- Advantages
  - Relative positions
  - Can accommodate large formations
- Disadvantages
  - Could easily be a mission in itself (but this may be a technology initiative)
    - Maintain that formation
    - Resolution issues
  - Cost
  - Difficult with large separation distances
  - Maturity: TRL 5??

♦ Super gyro: Gravity Pro B

- Description
  - Super Gyro and Commercial Star Tracker
  - Stripped down version of Gyro on the Gravity Pro B mission.
  - Utilizing computation schemes and longer observation times to obtain higher accuracies when looking at faint stars.

- Advantages
  - Can look any where in the sky
  - Stable over hrs to micro arcsec

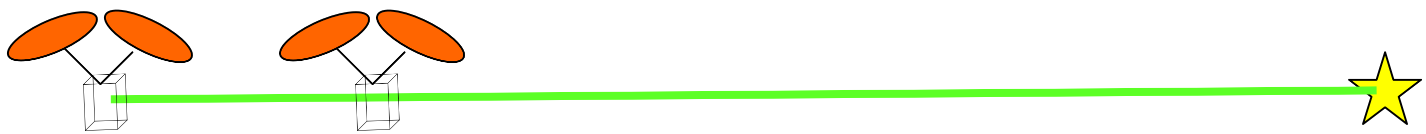
- Disadvantages
  - Thermal control: Uses Low temperature Super conductors
  - Cost!!!!!!
  - longer observation
  - Maturity: TRL 2

♦ Super Star Tracker:

- Description: advanced detector requiring less photons
  - Potential sensors will be examined in the ISAL
  - Uses a commercial Gyro
- Advantages
  - Micro arc seconds accuracy
  - Reduce computational time for attitude determination
  - Stable
- Disadvantages
  - Needs coarse star tracker (FOV issues)
  - Thermal stability:
  - Calibration time
  - Cost, power
  - Maturity: TRL ??

♦ Radio Interferometry

- Description
  - Two antenna on each vehicle to look at two stars to collect signals
  - One fast Computer to perform correlation of data to derived attitude



- Advantages
  - Maturity: has been done ➔ ARISE
    - One space antenna and one earth
    - Claim that it can achieve 100 μ arc-second resolution
  - Different wavelength
  - Can be used RF antenna for coarse acquisition
- Disadvantages
  - Power needed
  - Size of radio antenna
  - Computation power needed
  - Data rates ➔ bandwidth